Theoretical and experimental investigation on optimal measurement conditions for electron magnetic circular dichroic signals

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With the aids of the state-of-the-art inelastic scattering calculation and digitally controlled TEM-EELS systems, we quantitatively studied the energy loss by channeled electron (ELCE), which can provide site-specific EELS near edge structures (ELNES) [1]. A similar set-up (Fig. 1) of TEM-EELS provides a method to measure the magnetic circular dichroic signals in ELNES (EMCD), from which the magnetic and orbital moments of the probed element are expected to be analyzed with spatial resolution superior to the X-ray counter part of EMCD. Although EMCD measurements have been only qualitatively successful in several typical ferromagnetic metals due to their low signal to noise ratio, we have recently demonstrated quantitative analysis on nano polycrystalline Fe by a statistical treatment of STEM-EELS data cubes collected at an acceleration voltage, V, of 1000 kV [2]. In this poster, we investigate the measurement parameters of acceleration voltages [3], collection and convergent angles so as to acquire sufficiently large dichroic signals.

Figure 2 shows the experimental example ELNES collected with the EELS entrance aperture placed at A and B on the diffraction plane shown in the inset. The positions respectively enhanced the right- and left-handed circularly polarized dichroic signals of Co-$L_{2,3}$ ELNES. The dichroic signals of the difference spectra showed better S/N in the case of ultrahigh voltage TEM with V = 1000 kV, because of the larger fraction of the dichroic signals, which is here defined as $f_d = (I_B - I_A) / (I_A + I_B)$ at the L_3 peak energy. The experimental sample thickness was approximately 35 nm for both of the acceleration voltages.

Figure 3-a shows theoretical f_d as a function of sample thickness t, with several different collection angles ϕ_{col} represented as EELS aperture radii in units of g. The calculations were performed based on the dynamical diffraction and single core loss scattering. The optimum collection angles are less than 0.2 g because the larger ϕ_{col} significantly decreases f_d.

Qualitatively consistent with the experimental results, f_d with V = 1000 kV are significantly larger for relatively large thicknesses (t = 30 to 40 nm), because of larger effective thickness for the elastic and inelastic scattering of the fast electron, represented by the extinction distance and inelastic mean free path, respectively.

The ratio of f_d at 1000 kV to f_d at 200 kV is plotted as a function of thickness in Figure 3-b. The theoretical estimation is consistent with the experimental ratio within the experimental error bar of the thickness. Several error sources are conceived to underestimate the value: multiple-loss effects are more significant and the Co magnetization may not be fully aligned to the optical axis at the lower V, both of which are not taken into account in the present calculation.

References
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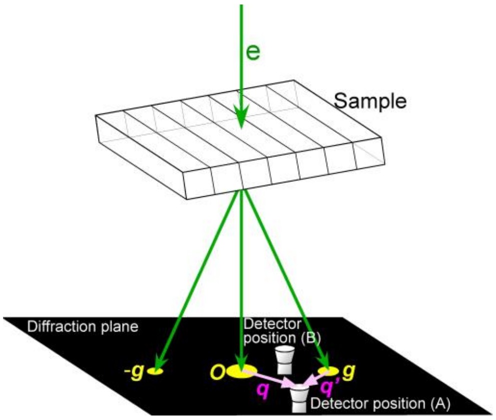

FIG. 1. Set-up of intrinsic EMCD measurement using the sample crystal as a beam splitter. ***q*** and ***q***' are scattering vectors for direct and diffracted beams falling into the EELS detector placed at (A).

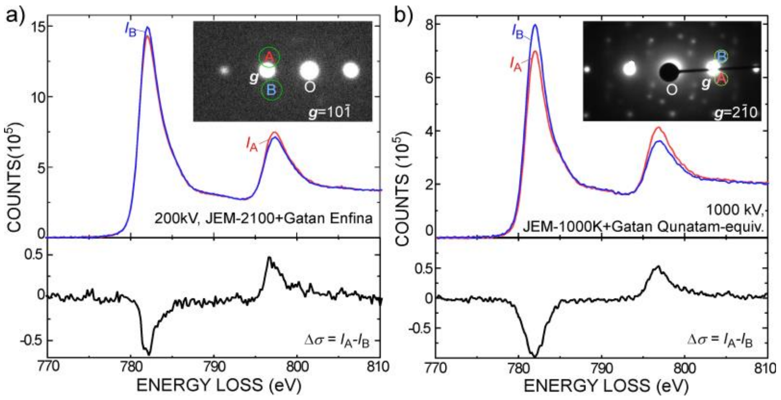

FIG. 2. Experimental Co-$L_{2,3}$ ELNES collected at two different EELS aperture positions (A), (B). Two sets of results obtained by using different TEM-EELS systems with different acceleration voltages are shown.

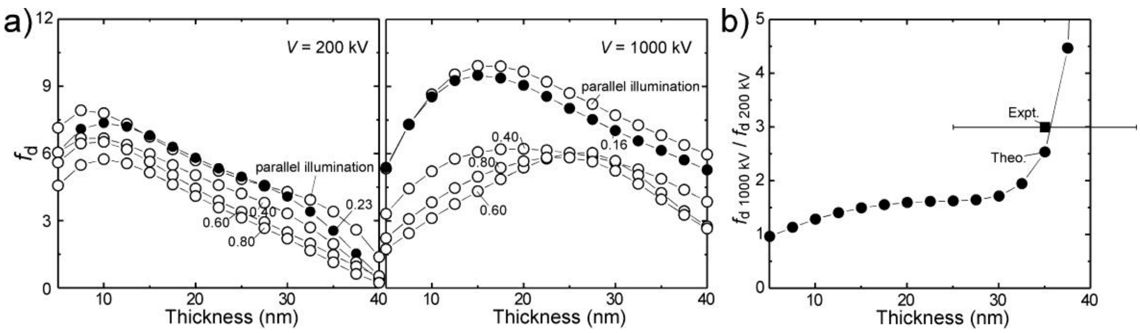

FIG. 3. (a) Theoretical f_d with V = 200 and 1000 kV. Numbers inset are ϕ_{col}, represented by EELS aperture radii in g. Filled circles are results with the experimental ϕ_{col}. (b) Theoretical and experimental ratios of f_d between V = 200 and 1000 kV.